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Performance Analysis of Concrete with Alccofine 1203 Additives and Replacements

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ABSTRACT

This study evaluates the influence of Alccofine 1203 on concrete properties, with a focus on workability, density, compressive strength, flexural strength, and split tensile strength. The experimental findings highlight that incorporating Alccofine 1203, characterized by its finer particle size and reduced water demand compared to Ordinary Portland Cement (OPC), leads to enhanced concrete performance. Notably, a 15% partial replacement of OPC with Alccofine 1203 significantly improved workability, yielding higher slump values for both M20 and M25 grade concretes.

Compressive strength tests revealed marked enhancements, with maximum strength achieved at 15% replacement. This improvement is attributed to the optimized particle size distribution of Alccofine 1203, which minimizes capillary voids and creates a denser, more cohesive cement matrix. Flexural strength increased substantially, with gains of 34.95% for M20 and 19.49% for M25 concrete mixes at the optimal replacement level. Similarly, split tensile strength exhibited significant enhancement, further reinforcing the mechanical benefits of Alccofine 1203.

The study concludes that Alccofine 1203 is an effective additive for elevating concrete performance. By increasing density, reducing voids, and forming a robust internal CSH gel structure, it significantly improves compressive, flexural, and tensile strengths. These findings underscore the potential of Alccofine 1203 to advance sustainable and high-performance concrete applications.

KEYWORDS: *Alccofine 1203, workability, compressive strength, flexural strength, split tensile strength, concrete performance*

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INTRODUCTION

The evolving demands of modern construction necessitate concrete with enhanced strength, durability, and extended service life, especially for critical infrastructure such as bridges, offshore structures, and pavements. (1) High-Performance Concrete (HPC) addresses these requirements by aiming to extend the lifespan of structures to approximately 100 years, far surpassing the conventional service life of 40–50 years. Achieving such performance improvements necessitate advancements in concrete quality, including a lower water-to-cement ratio, reduced segregation, and controlled heat of hydration.

In the context of India's rapid urbanization and increasing industrial activity, the challenge of managing waste production has highlighted the importance of sustainable construction practices. Industrial byproducts such as Alccofine have emerged as promising supplementary cementitious materials (SCMs), offering the dual benefit of improving concrete properties and reducing environmental impact. Alccofine, developed collaboratively by Ambuja Cement Limited (ACL) and the Alco Group, is recognized for its ability to enhance workability, durability, and mechanical performance of concrete. Research indicates that substituting 12–15% of Ordinary Portland Cement (OPC) with Alccofine 1203 significantly improves performance metrics, including compressive strength, water permeability, and durability, even under adverse conditions.

The distinct advantages of Alccofine stem from its ultrafine particle size and compact packing properties, which reduce voids in the wet cement matrix and enhance the density of the hardened concrete. This not only improves slump and workability but also contributes to superior strength development and long-term durability compared to traditional OPC mixes. Furthermore, the adoption of Alccofine in concrete production aligns with global efforts to minimize the environmental footprint of the construction industry by reducing reliance on clinker-intensive OPC.

In addition to Alccofine, advanced admixtures such as silica fume and liquid silica play a complementary role in improving concrete performance. By neutralizing calcium hydroxide (CH) formed during hydration, these admixtures reduce the heat of hydration, enhance the formation of calcium silicate hydrate (C-S-H) gel, and improve resistance to water ingress. This makes the concrete more resilient to aggressive environmental conditions, including chemical attack and temperature variations.

Integrating Alccofine and similar SCMs into concrete represents a significant step forward in pursuing sustainable and high-performance construction materials. These advancements not only contribute to the development of durable infrastructure but also address pressing environmental challenges associated with large-scale cement production, paving the way for greener and more resilient construction practices.

Literature Review

Environmental waste, often hazardous to health, is increasingly generated by industries like power plants, steel mills, and marble factories. This waste, if left unmanaged, poses significant environmental and health risks. However, it can be standardized with mineral additives and utilized in construction, offering dual benefits, lowering construction costs while promoting a cleaner environment. Using industrial byproducts like slag and fly ash as supplementary cementitious materials (SCMs) has gained attention as a sustainable approach to waste management. Researchers are actively exploring how these materials can improve concrete performance.

In this study, we investigate the effectiveness of Alccofine 1203 in concrete by partially substituting it with Ordinary Portland Cement (OPC). Alccofine, a glassy substance derived from slag, has shown potential in enhancing concrete's strength and durability. Various studies have highlighted its positive impact on concrete properties. For instance, Shah et al. (2020) demonstrated that a combination of 7% Alccofine and 25% fly ash yielded the highest strength in high-performance concrete. Similarly, Patel and Sheth (2014) found that quaternary mixtures containing Alccofine improved workability and compressive strength.

Further research by Pawar and Saoji (2013) revealed that Alccofine enhances self-compacting concrete's properties, such as filling capacity and separation resistance. Meanwhile, Nayak et al. (2014) compared Alccofine and silica fume, showing that Alccofine significantly improved compressive strength. Studies by Upadhyay et al. (2014) and others have consistently demonstrated that Alccofine, when used in appropriate proportions, enhances concrete's mechanical properties and durability.

This research aims to build on these findings by examining the effectiveness of Alccofine 1203 in various concrete mixtures, focusing on its potential to improve the sustainability and performance of construction materials. Through this investigation, we seek to contribute to the ongoing efforts to make construction more environmentally friendly and cost-effective.

Experimental Program

The experimental program focused on evaluating the performance of concrete with Alccofine 1203 as a supplementary cementitious material. The materials used included Ordinary Portland Cement (OPC 43-grade), natural sand as fine aggregate, and locally sourced coarse aggregate (10mm and 20mm). Alccofine 1203, known for enhancing workability and compressive strength, was incorporated at varying percentages. Aggregate gradation was conducted per IS-383:1970 standards. For fine aggregate, the fineness modulus was 2.65, falling within Grading Zone II. The coarse aggregate showed a fineness modulus of 1.65 for 10mm size and 2.5 for 20mm size.

The mix design involved control mixes for M20 and M25 grades of concrete, with and without Alccofine 1203. The mix proportions for M20 were 315 kg of cement, 678 kg of 20mm aggregate, 465 kg of 10mm aggregate, 769 kg of sand, 167 liters of water, and 3.15 kg of superplasticizer, yielding a water-cement ratio of 0.53. For M25, the cement quantity increased to 348 kg with corresponding adjustments to other materials and a water-cement ratio of 0.48. Concrete mixing was performed manually following IS-516:1959 guidelines. Fresh concrete was tested for workability using the slump test. Specimens were cast for compressive, flexural, and split tensile strength tests, with a total of 252 specimens for both M20 and M25 grades. Specimens were cured and tested at 7 and 28 days using a compressive testing machine.

This research aimed to optimize concrete mixes with Alccofine 1203 for enhanced performance, suitable for various construction applications. The findings contribute to the understanding of Alccofine's impact on concrete properties, offering a potential low-cost alternative for improving concrete quality.

Results and discussion

The results of the experimental work conducted to assess the impact of varying levels of Alccofine 1203 on the properties of concrete. Two types of concrete mixes, M20 and M25, were used with Alccofine either as an additive (0% to 15% by weight of cement) or as a replacement (0% to 15% by weight of cement). The experiments covered slump, density, compressive strength, flexural strength, and splitting tensile strength tests, and the results are compiled in tables and graphs for analysis.

Fresh Concrete: Workability Results

The workability of fresh concrete, evaluated through slump tests, is a critical parameter affecting its handling, compaction, and finishing properties. The inclusion of Alccofine 1203 in concrete mixes enhanced the workability by improving plasticity and flowability. The slump values for M20 grade concrete, both with the addition and partial replacement of Alccofine 1203, are detailed in Tables 1 and 2.

For M20 concrete, adding Alccofine 1203 led to increased slump values up to 10% replacement, beyond which the workability slightly decreased. This trend is consistent with the higher cohesion and reduced segregation achieved with controlled Alccofine 1203 addition. A comparison of slump values for both addition and replacement scenarios is summarized in Table 3. Similar trends were observed for M25 grade concrete, as presented in Tables 4.

Table 1: Slump Values for M20 Concrete with Alccofine 1203 Addition

Mix (Cement + Alccofine 1203)	Slump (mm)
OPC+Alccofine 1203 (100+0)	110
OPC+Alccofine 1203 (100+5)	150
OPC+Alccofine 1203 (100+10)	125
OPC+Alccofine 1203 (100+15)	108

Table 2: Slump Values for M20 Concrete with Alccofine 1203 Replacement

Mix (Cement + Alccofine 1203)	Slump (mm)
OPC+Alccofine 1203 (100+0)	110
OPC+Alccofine 1203 (95+5)	115
OPC+Alccofine 1203 (90+10)	127
OPC+Alccofine 1203 (85+15)	140

Table 3: Comparison of Slump Values for M20 Concrete

Alccofine 1203 (%)	Addition (mm)	Replacement (mm)
0	110	110
5	150	115
10	125	127
15	108	140

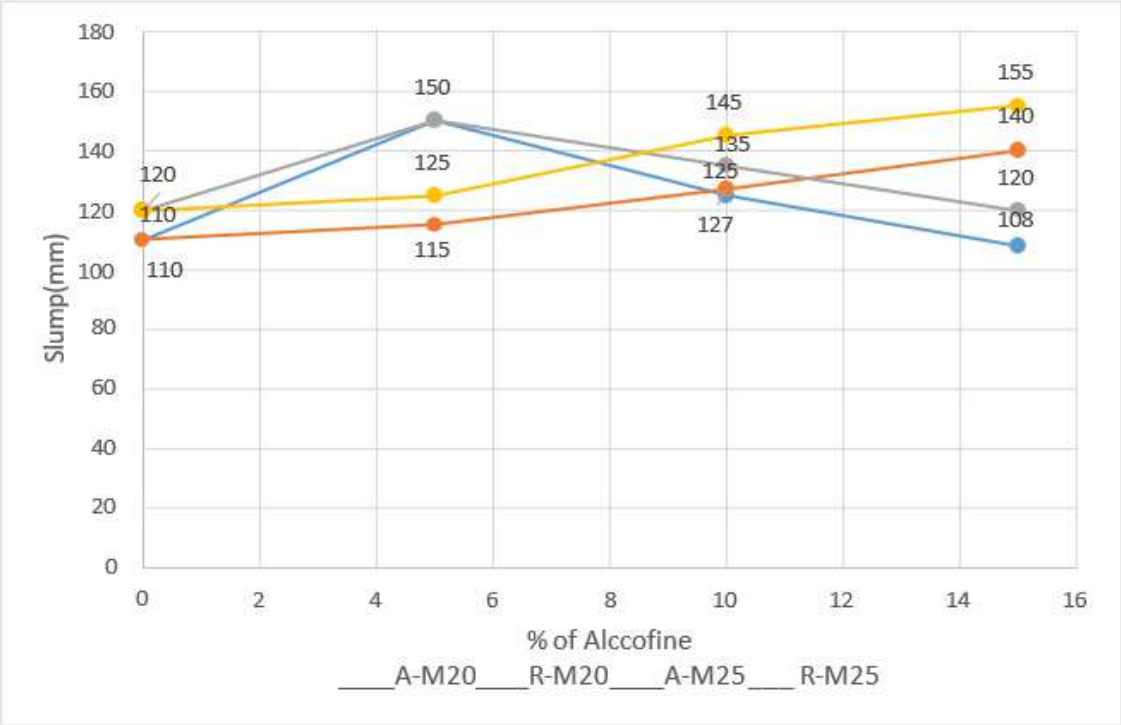

Fig. 1: Effect of Alccofine on Slump of Concrete (M-20& M25) on Addition & Replacement Hardened Concrete: Density Results

The inclusion of Alccofine 1203 had a notable effect on the density of hardened concrete. The density of M20 and M25 concrete mixes showed slight variations depending on the percentage of Alccofine 1203 used. Table 4 highlights the density changes for M20 grade concrete, whereas Table 5 presents the same for M25 concrete.

Table 4: Density of M20 Concrete with Alccofine 1203 Addition and Replacement

Alccofine 1203 (%)	Addition (Kg/m³)	Replacement (Kg/m³)
0	2476.19	2476.19
5	2467.30	2469.84
10	2499.05	2490.79
15	2516.19	2501.59

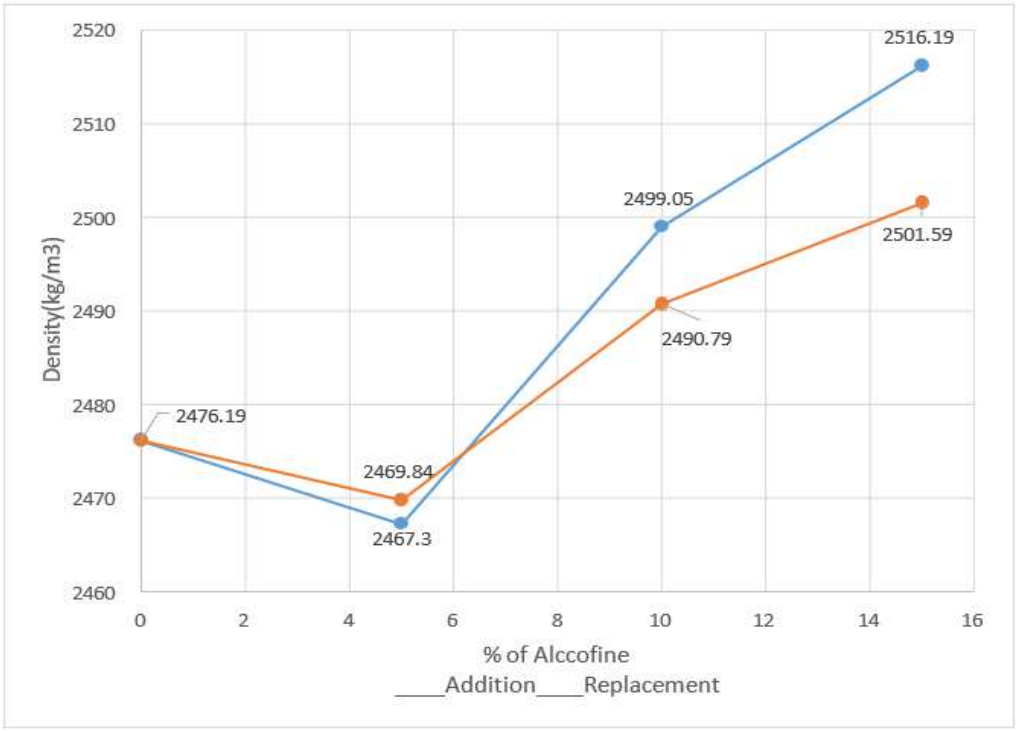

Fig. 2: Effect of Alccofine on Density of Hardened Concrete (M-20) on Addition & Replacement

Table 5: Density of Hardened Concrete on Addition of Alccofine into OPC &Replacement of OPC by Alccofine for M25

Alccofine 1203 (%)	Addition (Kg/m³)	Replacement (Kg/m³)
0	2421.33	2421.33
5	2434.54	2408.12
10	2426.99	2426.99
15	2440.20	2445.86

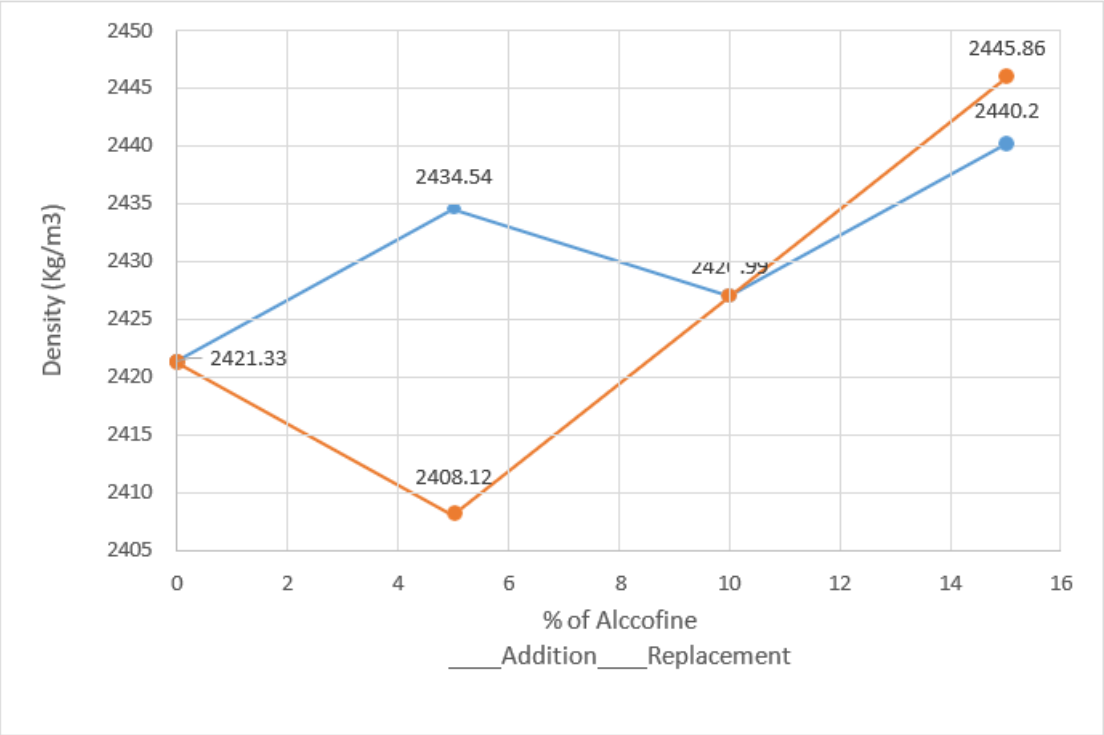

Fig. 3: Effect of Alccofine on Density of Hardened Concrete (M-25) on Addition & Replacement

Compressive Strength

Compressive strength tests conducted at 7 and 28 days demonstrated significant improvements with the inclusion of Alccofine 1203. Tables 6 and 7 detail the compressive strength results for M20 and M25 concrete, respectively. At 28 days, the strength increased significantly, particularly with 15% addition of Alccofine 1203, achieving a maximum of 41.19 N/mm² for M25 grade.

Table 6: 28-Day Compressive Strength for M20 Concrete with Alccofine 1203 Addition and Replacement

Alccofine 1203 (%)	Addition (N/mm²)	Replacement (N/mm²)
0	25.41	25.41
5	30.81	26.81
10	32.15	30.74
15	34.59	32.00

Table 7: 28-Day Compressive Strength for M25 Concrete with Alccofine 1203 Addition and Replacement

Alccofine 1203 (%)	Addition (N/mm²)	Replacement (N/mm²)
0	17.26	17.26
5	19.63	17.85
10	21.56	20.30
15	24.37	21.41

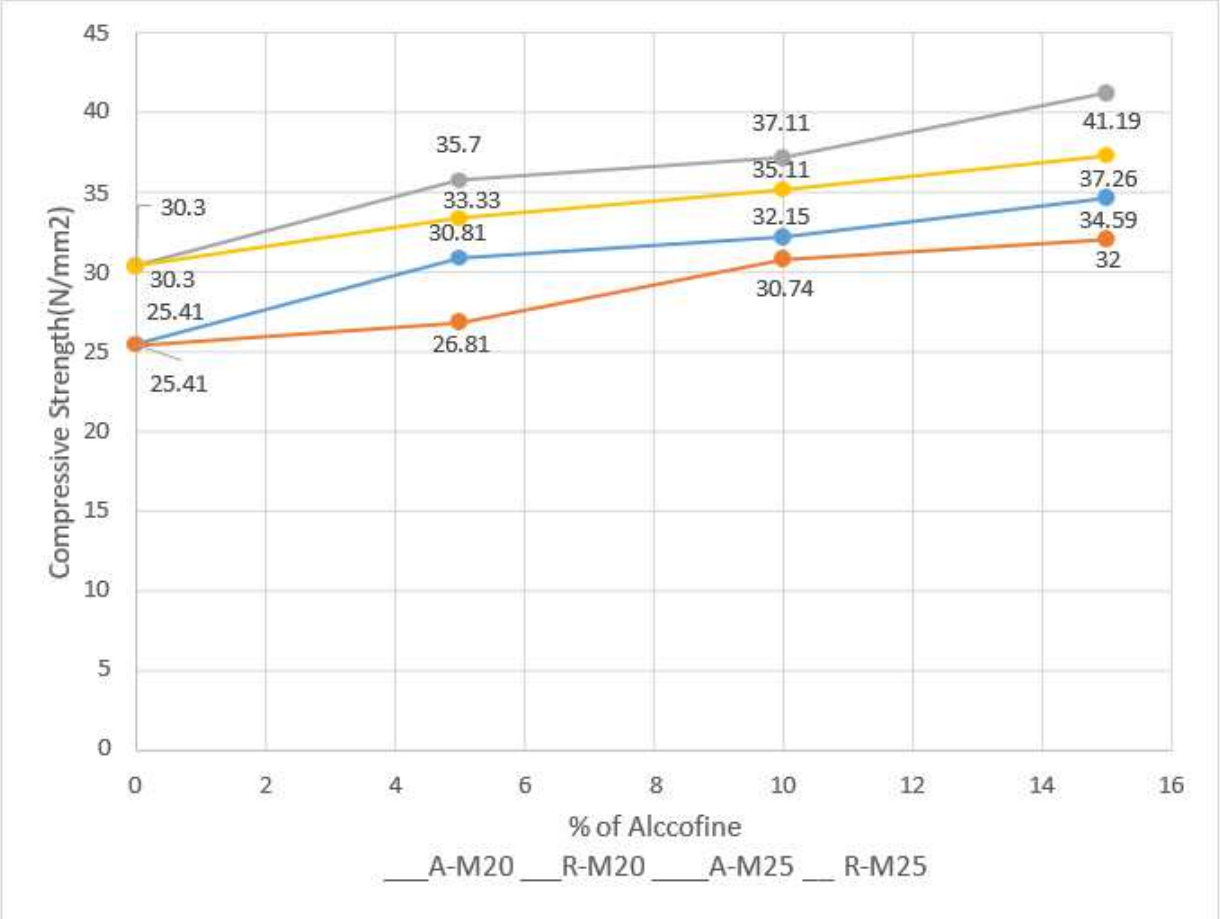

Fig. 4: Effect of Alccofine on Concrete (M20 & M25) Grade on Addition & Replacement for 28 Days Compressive Strength of Cube"

Tensile Strength

Tensile strength tests also indicated improvement with Alccofine 1203 usage. The maximum increase for M20 grade concrete was observed with 15% addition, where tensile strength increased by 19.70%. Table 8 summarizes the tensile strength results for both grades.

Table 6: Tensile Strength of M20 and M25 Concrete with Alccofine 1203

Concrete Grade	Mixture Type	Alcofine 1203Content	Tensile Strength (N/mm²)	Percentage Increase (%)
M20	ConventionalOPC	0%	2.76	-
M20	Alcofine 1203Addition	15%	3.30	19.70
M20	Partial Replacement withAlcofine	1%	3.11	12.67
M25	ConventionalOPC	0%	2.90	-
M25	Alcofine 1203Addition	15%	3.30	13.79
M25	Partial Replacement withAlcofine	1%	3.00	3.45

These results highlight that Alccofine 1203 significantly enhances both fresh and hardened concrete properties, making it a valuable addition or partial replacement in sustainable construction practices.

Splitting Tensile Strength of M20 and M25 Concrete

- Results for splitting tensile strength also improved when Alcofine 1203 was used. Table 4.25 presents the findings.
- By adding 15% Alcofine 1203, the splitting tensile strength of M20 concrete rose by 19.70%.
- When 15% Alcofine 1203 was added to M25 concrete, the splitting tensile strength increased by 13.79%.

Concrete Grade	Mixture Type	Alcofine 1203 Content	Splitting Tensile Strength (N/mm²)	Percentage Increase (%)
M20	Conventional OPC	0%	2.76	-
M20	Alcofine 1203 Addition	15%	3.30	19.70
M20	Partial Replacement with Alcofine	1%	3.11	12.67
M25	Conventional OPC	0%	2.90	-
M25	Alcofine 1203 Addition	15%	3.30	13.79
M25	Partial Replacement with Alcofine	1%	3.00	3.45

Conclusion

Water Usage: Alccofine 1203's lower water demand led to reduced water consumption in OPC mixtures. Partial replacement (15%) increased slump significantly (M20: 150–155 mm; M25: 155 mm).

Compressive Strength:

- Alccofine 1203 (15% replacement or addition) improved compressive strength in M20 and M25 grades.
- M20 compressive strength: 24.37 N/mm² (15% addition), 21.41 N/mm² (15% replacement).
- M25 compressive strength: 26.67 N/mm² (15% addition), 24.20 N/mm² (15% replacement).
- Target compressive strengths exceeded for both grades with optimized Alccofine content.

Flexural Strength:

- Adding 15% Alccofine 1203 to OPC increased flexural strength (M20: 34.95%; M25: 19.49%).

Split Tensile Strength:

- Split tensile strength improvement with 15% Alccofine 1203 addition (M20: 19.70%; M25: 35.45%).
- Splitting strength: M20 (3.30 N/mm² addition; 2.80 N/mm² replacement).

Density:

- Hardened concrete density increased in M20 and M25 grades with 15% Alccofine addition or partial replacement.

Material Behavior:

- Alccofine's finer particles reduced capillary gaps and formed continuous cementitious layers, enhancing strength.
- CSH gel formation from Alccofine improved internal microstructure and pore connectivity.

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